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THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

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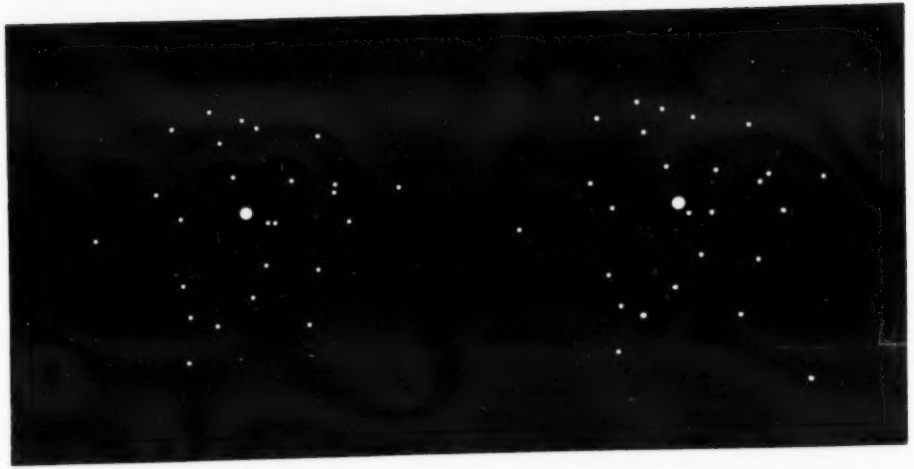

THE TWENTY-FIVE NEAREST STARS

A stereoscopic view, as seen from a distance of 100 light-years. The sun is at the centre.—*Drawn by R. K. Young.*

The duplicate copy of this plate bound herewith may be cut out for use in a stereoscope.

Journal of the Royal Astronomical Society of Canada, 1930.

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STEREOSCOPIC VIEW OF THE STARS NEAR THE SUN

With Plate XXIII

By R. K. YOUNG

The stars in the immediate neighbourhood of the sun are listed below in table I. Imagine yourself as viewing this group of stars from a distance of one hundred light-years. Place Plate X in a stereoscope and the stars will be seen in relief in their true positions relative to the sun, which is placed in the *centre* of the group:

TABLE I

Star	No.	α	δ	ρ	x	y	z
Proxima } α Centauri }		$14^h\ 33^m$	$-62°\ 15'$				
	1	14 33	−60 25	4.30	+ 1.67	− 1.31	+ 3.74
Barnard's star	2	17 53	+ 4 25	6.06	+ 0.19	− 6.04	− 0.47
Wolf 359	3	10 52	+ 7 36	8.07	+ 7.65	+ 2.35	− 1.07
Lalande 21185	4	10 58	+36 38	8.32	+ 6.43	+ 1.79	− 4.97
Sirius	5	6 41	−16 35	8.79	+ 1.48	+ 8.29	+ 2.51
B.D.−12°, 4523	6	16 25	−12 24	9.34	+ 3.68	− 8.34	+ 2.01
Innes	7	11 12	−57 02	9.59	+ 5.11	+ 1.09	+ 8.05
C. Z. 5h, 243	8	5 8	−44 59	10.3	− 1.64	+ 7.08	+ 7.28
τ Ceti	9	1 39	−16 28	10.4	− 9.04	+ 4.19	+ 2.95
Procyon	10	7 34	+ 5 29	10.5	+ 4.17	+ 9.57	− 1.01
ϵ Eridani	11	3 28	− 9 48	10.6	− 6.42	+ 8.23	+ 1.80
61 Cygni	12	21 02	+38 15	10.9	− 6.11	− 5.99	− 6.75
Lac. 9352.	13	22 59	−36 26	11.2	− 8.69	− 2.35	+ 6.65
Burnham 8798	14	18 42	+59 29	11.4	− 1.05	− 5.70	− 9.82
Groom. 34	15	0 13	+43 27	11.6	− 8.41	+ 0.46	− 7.98
ϵ Indi	16	21 56	−57 12	11.6	− 5.38	− 3.25	+ 9.76
Krüger 60	17	22 24	+57 12	12.7	− 6.29	− 2.79	−10.7
Van Maanen	18	0 44	+ 4 55	12.8	−12.5	+ 2.41	− 1.10
Lac. 8760	19	21 11	−39 15	12.9	− 7.40	− 6.70	+ 8.17
Anonymous	20	2 50	+52 05	13.6	− 6.15	+ 5.65	−10.7
Gould 32416	21	23 59	−37 15	14.8	−11.8	− 0.02	+ 8.9
Oe. Arg. 17415	22	17 37	+68 26	15.3	+ 0.56	− 5.60	−14.2
B.D.+20°, 2465	23	10 14	+20 22	15.8	+13.3	+ 6.59	− 5.48
Altair	24	19 46	+ 8 36	16.0	− 7.06	−14.2	− 2.38
o^2 Eridani	25	4 11	− 7 49	16.1	− 7.33	+14.2	+ 2.19

Figure 1 gives identification numbers which correspond to the left hand diagram in Plate XXIII and to the numbers in Table I, second column. The last two columns in the table give the y and z co-ordinates expressed in light-years. Both co-ordinates are in the plane of the paper, which is perpendicular to the direction in which the observer is viewing the cluster. The y co-ordinate is the abscissa, positive toward the right and the z co-ordinate is the ordinate positive upwards. The scale is such that 1.6 mm. equals one light-

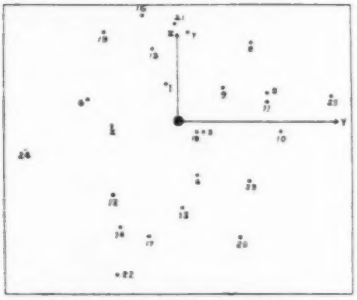


Fig. 1.—Key to Stars in Plate.

year. The x co-ordinate is perpendicular to the plane of the paper and is the direction in which the observer is looking. When viewed in the stereoscope, those stars which are listed with positive x co-ordinates will appear more remote than the sun and those which are listed with a negative x co-ordinate will appear between the observer and the sun. Table I also gives ρ, which is the distance of the star from the sun in light-years, and is numerically equal to the square root of $x^2+y^2+z^2$. For further information about these stars, magnitude, type, etc., the reader may consult the *Handbook*, page 62.

THE PROBLEM OF THREE BODIES*

By Daniel Buchanan

Ever since the appearance of Cain upon the earth, the third body has been a problem. He was not the first to disturb the steady state of the original two-body pair that moved uniformly within a given region—a region, unfortunately, not devoid of singularities. But when once a singularity had been passed with its consequent transformation of the motion to a different manifold, the third body was undoubtedly the predominant factor in subsequent perturbations in the new manifold. When the field was first enlarged to include a fourth body, recorded observations show that the mutual reactions of the third and fourth bodies resulted in the annihilation of the fourth body and in a *marked* alteration in the path of number three. The inference is that the fourth body should not enter the problem until its influence upon No. 3 can be predicted. Final records show, however, that a complete solution of the third body is possible inasmuch as another fourth body, emanating from an unknown source and undoubtedly bearing more attraction than repulsion, was so introduced that the resultant motion was regular except for essential singularities.

But the purpose of this paper is not to discuss the problem of three bodies in an ethnological sense as it relates to the origin of the race, but in a dynamic sense as it pertains to motion in general and to the sun-earth-moon system in particular.

The problem is

> Given three bodies of finite mass which move under their mutual attractions according to the Newtonian law of the inverse square, to find, in terms of the time and initial values, expressions for their positions relative to a system of co-ordinate axes which will hold for all values of the time and for general initial conditions.

The differential equations of motion consist of 9 equations of the second order, viz.:

*Presidential address to Section III, Royal Society of Canada, Montreal, May, 1930.

$$m_1 \frac{d^2x_1}{dt^2} = -k^2m_2 \frac{x_1-x_2}{r^3_{12}} - k^2m_3 \frac{x_1-x_3}{r^3_{13}},$$

$$m_1 \frac{d^2y_1}{dt^2} = -k^2m_2 \frac{y_1-y_2}{r^3_{12}} - k^2m_3 \frac{y_1-y_3}{r^3_{13}},$$

$$m_1 \frac{d^2z_1}{dt^2} = -k^2m_2 \frac{z_1-z_2}{r^3_{12}} - k^2m_3 \frac{z_1-z_3}{r^3_{13}},$$

with six more equations obtained by cyclically permuting the subscripts on x, y, z. The masses are represented by m_1, m_2, m_3; their coordinates by x_1, y_1, z_1; x_2, y_2, z_2; x_3, y_3, z_3, respectively; and the distances between m_i and m_j by r_{ij} $(i, j=1, 2, 3, \ldots)$. The factor of proportionality is k^2. It is required to find solutions of these differential equations which will converge for all values of t and which for $t=0$ will reduce to $x_i=a_i$, $y_i=b_i$, $z_i=c_i$ $(i=1, 2, 3)$.

Nearly all the great mathematicians from the time of Newton have directed their attention to this problem. Outstanding among them are Euler of Switzerland; Clairaut, Laplace, Poisson, Cauchy, Delaunay, Tisserand, Poincaré of France; Gauss, Jacobi, Weierstrass of Germany; Newton, Adams, Darwin, Brown of England; Lagrange, Levi-Civita, Bisconcini of Italy; Hill, (Brown), Newcomb, Moulton, Birkhoff of America; Strömgren of Denmark—to mention only a few of the more outstanding. The three following phases of the problem have been considered at various times, viz., (1) to find particular solutions, (2) to find that there is a general solution, and (3) to find that there is no general solution. The proof of the existence of a general solution baffled all mathematicians of all races and of all centuries until the year 1911 when a somewhat obscure mathematician, Karl F. Sundmann, a native of Helsingfors in the obscure country of Finland, startled the mathematical intelligentsia of the world by the publication in a Finnish journal of a treatise giving a complete and general solution. So highly was the paper considered that Mittag-Leffler, editor of the *Acta Mathematica*, where are to be found so many outstanding researches, particularly contributions by Darwin, Poincaré and Weierstrass, invited Sundmann to re-publish his paper in the *Acta*. Who knows but what the esteemed editor of the *Acta* may not have been influenced by the inarticulated desire of the mathematicians of the past, at last removed from regions where envy lurks, that

honour should be done him who completed what they had begun and who was successful where they had failed? But to prevent undue 'undulation' it must be emphasized that while the problem is completely solved it is by no means finished, as the form of the solution leaves much to be desired.

To comprehend more clearly the difficulty in the problem of three bodies it will help us if we consider first the two-body problem.

The solution of the two-body problem culminated in Newton, without whose discovery of the laws of motion and of the law of gravitation the problem would have remained unsolved. Earlier contributors were Hipparchus and Ptolemy, who postulated ingenious systems of cycles and epicycles to account for the orderly motion of the heavenly bodies—an order observed from the remotest antiquity. Next in importance came Tycho Brahe, who made extensive observations of the motions of the planets over a period of years and carefully recorded his results. Using Brahe's observations, Kepler endeavoured to make the observational data conform to a beautiful and fanciful conception he held as to how the solar system moved. He was familiar with the fact that there are five regular polyhedra; the tetrahedron, the cube, the octahedron, the dodecahedron, and the icosahedron. Kepler was convinced that the relative distances of the planets are the same as the relative radii of certain spheres that can be inscribed in, and circumscribed about, the various polyhedra. For example, we start with any sphere S_1 and about it circumscribe a polyhedron,—the tetrahedron for example. Through the vertices of the tetrahedron a second sphere S_2 is circumscribed. About S_2 a second polyhedron is drawn and through its vertices a third sphere S_3. In this way six spheres are obtained and their six radii should give, according to Kepler, the relative distances from the sun of the six members of the solar system then known, viz., Mercury, Venus, Earth, Mars, Jupiter, Saturn. There are 120 ways of arranging these polyhedra and spheres, but in vain did Kepler try to obtain an arrangement which would conform to Brahe's data. Very reluctantly did he abandon his beautiful idea, perhaps not without the conviction that if the solar system were not so ordered, it should have been. When nature was so thoughtless as to ignore such an ideal mathematical arrangement, Kepler's faith began to wane and he became extremely

heretical. He began to wonder, covertly at first no doubt but at last openly, as to whether a planet might not move in an orbit other than the orthodox circle or epicycle. After working on the orbit of Mars for eight years he abandoned the faith of Hipparchus and Ptolemy, which had confined the world within their crystalline spheres for centuries, and enunciated his famous laws of planetary notion. They are as follows:

1. The orbit of every planet is an ellipse with the sun at a focus.
2. The radius vector joining the planet to the sun sweeps over equal areas in equal intervals of time.
3. The squares of the periodic times of two planets are proportional to the cubes of their mean distances.

Kepler's laws are empirical. They agree with observed planetary motions but they do not account for them. Thoughtful men who had been shown "how" were beginning to wonder "why." Then one day a native of the village of Woolsthorpe saw an apple fall. To be sure it was not an unusual phenomenon nor was it the first time such an observation had been made. But it was an unusual observer, viz., Isaac Newton, and he attached a new significance to an oft-observed phenomenon. The apple seems to occupy a unique position in its relation to the race (and I do not hold any brief for the O.K. Fruit Growers). The eating of the apple led to the fall of mankind while the fall of the apple led the giant intellect of Newton to "think God's thoughts after Him." From Kepler's laws he made the following deductions: from Kepler II, that the force of attraction is directed towards the sun; from Kepler I, that the force of attraction varies inversely as the square of the distance; from Kepler III, that the attraction of the sun for a unit mass of any of the planets would be the same if the masses were at the same distances.

Let us now return to the three-body problem. To illustrate its difficulty, let us consider only the sun-earth-Jupiter system and neglect all the other planets and satellites. If the influence of Jupiter is neglected, the earth will move in an ellipse E_1 with the sun at a focus. Likewise if the influence of the earth is neglected, Jupiter will move in an ellipse J_1 with the sun at a focus. As Jupiter moves in J_1 it will pull the earth from E_1 to E_2, and simil-

arly the earth moving in E_1 will pull Jupiter from J_1 to J_2. The displacements from E_1 to E_2 and from J_1 to J_2 are called perturbations of the first order. Next Jupiter moving in J_2 will displace the earth from E_2 to E_3 and the earth moving in E_2 will displace Jupiter from J_2 to J_3—thus giving perturbations of the second order. These second order perturbations give rise to those of the third order and so on in an unending series. The perturbations decrease in magnitude with their order but there is likewise a rapid increase in their complexity.

The first attempt to treat perturbations was made by Newton in the *Principia* for the sun-earth-moon system. He conceived the moon as moving in an ellipse whose size, shape and position are constantly changing. His methods were geometric and while they are more cumbersome and less powerful than the later analytic methods, he secured results to a considerable degree of approximation except for the motion of the moon's perigee. His treatment of the moon was characterized by Sir George Airy as "the most valuable chapter that was ever written on physical science."

The immediate followers of Newton were Clairaut (1713-1765), d'Alembert (1717-1783) and Euler (1707-1783). Clairaut's work on the moon was chiefly Newtonian. He gave a satisfactory explanation for the motion of the apse of the moon's orbit which had previously puzzled astronomers. He was on the point of advancing a modification of the law of gravitation to account for the phenomenon when the computations of the third order perturbations solved the puzzle.

D'Alembert's chief contributions in this field were related to the precession of the equinoxes and to the variations in the obliquity of the ecliptic. His methods were almost entirely analytical.

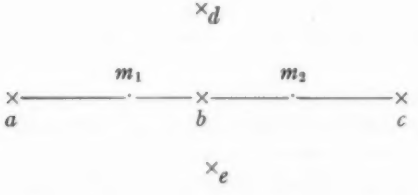
Euler considered the moon as carrying three rectangular axes always moving parallel to themselves and with respect to which the motion was referred. While this method was very cumbersome it nevertheless enabled Mayer to construct lunar tables for which a posthumous grant of £500 was made by the English parliament in 1770.

While these three men, guided by their keen physical intuitions, obtained certain of their results by methods of approximations which were not proved to converge, they had nevertheless not

neglected rigorous demonstrations. They obtained ten of the $6n$ integrals which are sufficient for the solution of the n-body problem. Six of these integrals show that the centre of gravity of the system moves uniformly in a straight line; three more, the integrals of area, show that the sums of the products of the masses and the projections of the areal velocities on the reference planes are constant; and the tenth integral, the *vis viva*, shows that the total energy of the system (potential and kinetic) is constant. Bruhns later demonstrated that no new algebraic integrals exist, and Poincaré still later showed that no new uniform transcendental integrals exist for the three-body problem even when the masses of two of the bodies are small compared to the mass of the third.

Following Euler and his contemporaries were Lagrange (1736-1813) and Laplace (1749-1827). Lagrange, a native of Italy, some time resident in Berlin at the court of Frederick the Great,—"the greatest mathematician in Europe," a guest of "the greatest king in Europe,"—was no doubt the most outstanding mathematician of the 18th century. His celebrated memoir of 1772 was the first to exhibit certain exact solutions. These are the well-known straight-line and equilateral-triangle solutions.

If two masses m_1 and m_2 are given, there are three points, a, b, c, points of libration or of equilibrium as they are called, on the line adjoining m_1 and m_2 at which a third body m_3 may be placed and initially projected so that it will always remain in the same position relative to m_1 and m_2. Two other such points, d, e, are at the vertices of the equilateral triangles described in the plane of motion of m_1 and m_2 and having the join of these two masses as base. If a body is placed at any one of these five points and given the proper initial projection, the three bodies will describe similar orbits, circles or ellipses. Both sets of exact solutions have little or no practical applications. It was first suggested by the Swedish astronomer Gylden that the phenomenon known as the gegenschien may be



accounted for by the possibility of numerous meteors, when passing near the libration point on the side of the earth remote from the sun, lingering for a revolution or two to explore the strange region of repose where "push" and "pull" exactly counterbalance.

The equilateral-triangle libration points were first advanced by Lagrange as "pure curiosities," but comparatively recent discoveries of the so-called Trojan groups of planetoids near the equilateral-triangle equilibrium points with the sun and Jupiter as base show that pure curiosities may sometimes develop into concrete realities.

In this age when so much attention is directed to the development of electricity for power and light, it may seem as a tremendous lack of foresight in sun-earth-moon planning that the moon was not placed at the equilibrium point now occupied by the gegenschein. If that were the case, as Laplace first showed, we should always have full moon. It would appear rather smaller than at present, but it would always be full. But this arrangement would not be without its disadvantages. In the first case there would be no changes in the moon to blame for the unusual weather everywhere prevalent; and in the second case, as shown by Liouville in 1845, there would be no moon at all after a certain period, as the moon would then be outside the region of stability of the sun-earth-moon system and the effect of planetary perturbations would cause it to wander to parts where its reflected light would diminish and eventually disappear.

While Laplace's name suggests his famous nebular hypothesis, which had a profound influence upon the science and philosophy of the 19th century, he also made contributions to the problem of three bodies. Along with Lagrange he showed that the general problem could be integrated completely if the ratios of the mutual distances were assumed to be constant. In his twenty-fourth year he gave a demonstration purporting to show the stability of the solar system, *i.e.*, that the expressions for the major axes of the planetary orbits contain no secular terms and therefore will not increase indefinitely with the time. Thus Laplace at an early age exhibited a complex for world problems. While his conclusions concerning stability brought a certain sense of security to the more timorous, his method of demonstration was far from satisfactory.

Differential equations were broken up and terms dropped in a manner which could not be logically justified. The process was not proved to converge and terms of the second and higher orders were not considered. Poisson later considered terms of the 2nd order and his results confirmed those of Laplace, but Poincaré showed that the process does not converge. His demonstration should not undermine our faith in the security of the solar system as the changes involved are extremely slow.

After Lagrange and Laplace little or no progress had been made in the problem of three bodies for over a century. The next contribution to the problem was made on this side of the Atlantic by one of English-Huguenot descent, viz., G. W. Hill (1838-1914), who for more than thirty years performed the routine duties connected with his position in the American Nautical Almanac office, but spent his leisure hours in the study of celestial mechanics. His greatest contrubution was his celebrated work on the lunar theory.

As already pointed out, the moon's motion was first considered by Newton from the standpoint of the varying ellipse, and for more than a century after his time this method was still employed, simplified and enhanced by the introduction of the more powerful methods of analysis. The culminating treatment of the varying ellipse was that given by Delaunay in his epochal work published in 1860. He started with the five elements of the moon's orbit undisturbed by the attraction of the sun. These elements were then considered to vary under the sun's attraction and five new constants were introduced which specify how the elements vary. These variations just considered would produce changes in the disturbing force of the sun and it became necessary to vary the constants introduced at the preceding stage. This necessitated the introduction of a new generation of constants with their consequent disturbing forces and so on from generation to generation in unending series. Delaunay developed in a systematic way processes for varying first the elements and then the equivalent constants at successive steps. The final literal series which he obtained for the three coordinates of the moon occupy several hundred quarto pages and represent the work of more than twenty years. His death terminated his work before he succeeded in reducing the literal coefficients to numerical values.

The work of Hill marked a new epoch in lunar theory. He discarded the varying ellipse of Newton as a starting point and began with a particular exact solution as a first approximation. By means of mechanical quadratures he obtained expressions for the coordinates with a high degree of precision. He neglected, however, a small part of the disturbing action of the sun, the "parallactic terms," and his treatment therefore did not constitute a solution in the strictest sense of the term. Furthermore, he did not prove the convergence of the series he employed. His work gave rise to differential equations with periodic coefficients, the solutions of which he obtained by means of infinite determinants.

Hill did not live to complete the work on lunar theory. This was done by Brown, who developed the theory on the basis laid down by Hill. While Hill conquered the initial difficulties, Brown through an enormous amount of work brought the lunar theory to its present satisfactory basis.

Mention should be made of Darwin, who exhibited various types of periodic orbits, his results being obtained chiefly by arithmetical processes. Moulton, on the other hand, gave rigorous demonstrations of the existence of various periodic orbits; and by his development, along with MacMillan, of the theory of differential equations with periodic coefficients he devised elegant methods for constructing various periodic solutions.

Let us now consider the development of the problem which led to Sundmann's solution.

Ever since the time of Euler it has been known that formal solutions of the differential equations of motion can be expressed as:

$$x_1 = a_1 + t\left(\frac{dx_1}{dt}\right)_{t=0} + \frac{t^2}{\underline{|2}}\left(\frac{dy^2_1}{dt^2}\right)_{t=0} + \ldots,$$

$$y_1 = b_1 + t\left(\frac{dy_1}{dt}\right)_{t=0} + \ldots$$

$$z_1 = c_1 + t\left(\frac{dz_1}{dt}\right)_{t=0} + \ldots$$

The first derivatives are arbitrary. The second derivative can be obtained from the differential equations, and the subsequent derivatives can be obtained from the first and second derivatives. About 100 years after Euler, Cauchy proved that expansions of this

kind converge for values of the time not too large, provided there are no collisions between any two of the bodies at the origin of time. While these expansions, therefore, constitute a solution which is valid for sufficiently small values of the time, they do not show whether the motion is periodic or whether there will be collisions or infinite separations. Further, the expansions give no information concerning the existence or location of singular points, viz., poles where the co-ordinates become infinite and branch-points where the derivatives become indeterminate. Painlevé proved that there are singular points in the solution only for collisions for real or complex values of t. Levi-Civita showed that in the case of the restricted problem (one mass infinitesimal, the finite masses moving in circles) it is possible to determine the character of the motion near collision without difficulty and that the only singularities are branch-points. This was later shown by Bisconcini to be the case in the general problem when the three masses are finite, but he made an assumption which seemed evident but which he was unable to prove, viz., that the angular velocity of the radius vector of two bodies which collide remains finite as the time approaches the instant of collision. The contribution made by Sundmann which marked the climax of the solution of the problem was to substantiate the assumption made by Bisconcini. While no attempt should be made to belittle the profound results of Sundmann, it must be stated that they are disappointing as they give no information concerning the properties of the motion and are unsuitable for practical applications.

The contributions of Poincaré, on the other hand, are more profound and more diversified, not only in their theoretical aspects but also in their practical applications. If it was not his lot to put the coping stone on a structure which others had all but completed, it was his greater fortune to lay the foundations for, and to erect no inconsiderable portion of, a structure more gigantic, more elegant and more useful. There was not one of his 1,500 papers and treatises which did not show something worthy of his "wonderful imagination, penetrating intuition and unerring logic." His first problem in the field of celestical mechanics was a consideration of the stability of the solar system. As already stated, there is no rigorous answer to this question, but Poincaré showed that solu-

tions exist which are purely periodic. If the solar system is fortunate enough to be moving according to Poincaré's somewhat belated specifications there is no danger of disaster through collision with, or infinite recession from, the central mass.

In the restricted problem of three bodies, Poincaré showed the existence of an infinity of geometrically distinct periodic orbits, provided the second finite mass is sufficiently small. The expansions for these orbits converge for all values of the time but for sufficiently small values of certain parameters which are functions of the linear dimensions or of the periods. He discussed also periodic orbits of the second genus, asymptotic orbits and doubly periodic orbits.

The contributions of Birkhoff approach those of Poincaré in generality and profundity. He extended the work of Levi-Civita to show that the only singularity corresponds to the rejection of the particle to infinity. Hill, Darwin, Moulton, Poincaré, and others had shown by analytic methods the existence of periodic orbits of simple type, both direct and retrograde. These orbits exist for sufficiently small values of one of the masses or for a sufficiently large value of the constant of Jacobi. Birkhoff demonstrated that so long as the particle is confined to an oval of zero velocity about one of the bodies there necessarily exists at least one retrograde orbit of simple type. The direct orbits he found not so amenable to existence. The analytic method further requires a limitation on a parameter involved in order that the period of the solution shall be finite. Following the work of Hadamard, Hilbert, Whittaker, Signorini, Tonelli, and others, Birkhoff interpreted periodic orbits as geodesics on a surface and showed that the possibility of an infinite period does not arise in certain types of problem. In his last paper Poincaré showed if a certain geometric theorem is true that the existence of a ring transformation for the differential equations of motion in the restricted problem carries with it the existence of an infinite number of periodic solutions. This geometric theorem was proved later by Birkhoff.

The work of Strömgren, with his able corps of assistants at Copenhagen, is of an entirely different character from that of Birkhoff or Poincaré. Following more the method of Darwin, he is exhibiting from time to time a wide variety of periodic orbits.

In conclusion it must be stated that this summary of the problem of three bodies deals only with the Abrahams who journeyed into strange lands to claim new kingdoms; with the Gideons, Baraks, Samsons and Samuels, who subdued those kingdoms, wrought works of rigour, waxed valiant in achievement, turned to flight the armies of difficulties. Time would fail to tell of other pioneers who in no small degree have likewise made their contribution in this historic field. In certain respects the conquest has been complete, in others only partial.

University of British Columbia,
Vancouver, B.C.

RADIO TALKS OVER CFCF

By W. E. Harper

XXIX.—MORE ABOUT THE MOON

(March 12, 1930)

In my ten minute chat with you this evening on Astronomy, I am going to discuss some phenomena connected with the moon, most of which phenomena are extremely simple.

1. *Does the size vary?* In our Saturday night talks to visitors at the Observatory, we are often asked the question why the moon is larger near the horizon than when it is higher up in the sky. There is a prevailing impression that such is the case, and as the lunar orb is full in a few days now, you can test the matter out for yourselves. By holding a coin a definite distance from the eye until it completely obscures the moon on the horizon, it will be found that the same distance will be required to mask it out when it is high up in the sky. To be strictly accurate, it is slightly smaller on the horizon because then it is farther away than when higher up. Moreover, on the horizon refraction bends the lower limb upwards more than the upper, and thus causes a compression in the vertical diameter.

But overlooking such refinement of our measure, we may say that it has the same angular diameter whether seen on the horizon or in the zenith, and the question naturally arises as to the the cause of the illusion. It is purely psychological and, among other causes, possibly the fact that near the horizon there are trees or other objects with which to compare it, causes it to have an appearance of bigness which is lacking where no such comparisons can be made.

2. *Quantity of Moonlight.* As everyone knows, moonlight is simply sunlight reflected from the moon's surface. Its brightness as compared with sunlight is difficult to measure accurately, but the mean of the best determinations shows that the sun gives about half a million times as much light as that of the full moon. More-

over, after reflection from the moon's surface, the light is more yellowish in quality, so that the photographic brightness is even less than the visual. Without thinking about it, we might expect that at the time of half moon the total light received would be half that of full moon. Due to its extremely rough surface, however, much of the illuminated surface is hidden from us by mountain peaks, and in consequence, only about 12 per cent., instead of 50 per cent., reaches us at such a time.

3. *Phases Complementary.* The so-called phase of the moon is simply the amount of the illuminated surface which is turned towards us at any particular time. At new moon it is directly between us and the sun, and we see none of its illuminated hemisphere. A few days later a thin crescent shows, which gradually increases to the half and full phases. A man on the moon, if such there were, would see the earth passing through phases like those which we see the moon undergoing, only they would be in a different order. Thus, at new moon, when it is blank to us, to him it would be full earth; in the early crescent stage of the moon the earth would appear, not wholly, but almost wholly illuminated. The time of half moon to us would be half earth to our moon-man. The phases would be always complementary to each other, that is to say, the fractions of each illuminated surface would add up to unity.

4. *Earth-shine.* Now in the crescent stage of the moon when, let us say, one-tenth of its hemisphere shows bright, the other nine-tenths is seen to be faintly illuminated. This is often popularly spoken of as the "old moon in the new moon's arms". This faint illumination comes from the earth, which, at such a time, as just intimated, is nearly fully illuminated. That is to say, the bright crescent is due to direct rays from the sun, while the fainter portion is due to rays which have come to the earth and been reflected back to the dark side of the moon. Earth-shine is the term appropriately applied to such illumination, and it is visible for several evenings after one sees the crescent in the evening sky. Its brightness diminishes rapidly as the half moon stage is reached. The same condition holds, of course, for the waning moon. An amateur in France the past summer has made very accurate determinations

of the brightness of the earth-shine at various stages, and that, too, by simple apparatus constructed by himself.

5. *Ring around the Moon.* Occasionally one sees a ring of light around the moon, and some budding weather forecasters immediately predict an approaching storm. And there is some justification for such prophecy because the very presence of such a phenomenon indicates that the upper atmosphere is heavily laden with ice crystals. These have the property of bending the light falling on them from the moon in much the same way that a prism bends or refracts light incident upon it. Due to the particular shape of the crystals and certain optical considerations, the ring of light is always at the same angular distance from the moon, approximately 22°. The blue end of the spectrum is considerably weakened and what we see has a yellowish or reddish tinge.

6. *Moonbows.* While rainbows are common enough phenomena, especially during showery weather in the summer time, the corresponding bow due to the light of the moon is not so common. It is just possible that many have never witnessed it, but the same causes that operate to produce a rainbow in the daytime are equally effective to give us a moonbow at night. Since we learned a moment ago of the extreme faintness of moonlight relative to sunlight, it is only reasonable to expect that such phenomena will be witnessed only near the time of full moon. As with the rainbow, so with the moonbow; it will be seen in the quarter of the heavens directly opposite the moon, and each observer will see his own particular moonbow.

7. *Moon without an Atmosphere.* To an imaginary observer on the moon, our earth would present a changing spectacle. The contrast between snow fields and areas of green vegetation, would be softened by our enveloping atmosphere, and as clouds formed and dissolved, an ever changing panorama of light and shade would be witnessed. It is different with us looking at the moon. Due to its small mass, it has not been able to hold an atmosphere, a fact which is substantiated by various lines of evidence. In the first place the intense blackness of the shadows cast by the mountain peaks would almost be a sufficient argument against the presence of an atmosphere. More conclusively is it established by the ab-

sence of any dimming effects on the light of a star when the moon comes between the star and ourselves. If an atmosphere were present, it would be densest at the moon's surface, and consequently a star should gradually dim down as the moon occulted it. In every case the star preserves its brightness undiminished until the instant of total extinction. Photographs of recent date on plates sensitized to ultra-violet and extreme-red light show absolutely no difference in the contrast of the shadows, again emphasizing the complete absence of an atmosphere.

8. *Markings, and what they mean.* Dark and light areas are seen on the moon's surface, but these are always the same at each succeeding phase. Speaking broadly, the brighter portions are the higher table lands and mountain ranges and peaks, while the darker portions are the lower lying levels or valleys, which are in shadow. Such extensive dark regions, when viewed through a telescope, are seen to be smoother than adjacent bright regions, as if they represented the floor of former ocean beds. To the naked eye these darker patches near the time of full moon take on the form of a human being, and thus we have the popular fancy expressed in such terms as "the man in the moon", "the Gibson girl", and others of a similar nature.

XXX.—THE DISCOVERY OF PLANETS

(April 11, 1930)

As considerable interest has been attached to press despatches announcing the discovery of a new planet at the Lowell Observatory in Arizona, a brief talk on such discoveries would seem to be quite in order.

The word planet means wanderer and was suggested by the Greeks as a name for the five bright bodies, Mercury, Venus, Mars, Jupiter and Saturn, which wandered back and forth among the fixed stars. We have come to recognize these as bodies giving out no light of their own, but shining rather by sunlight reflected from their surfaces. Counting in the earth, there were thus six planets known to the ancients. These, as we now know, revolve about the sun, Mercury requiring 88 days to make a complete revolution,

Venus 225 days, Mars 687 days, Jupiter 11.9 years, and Saturn 29.5 years.

The first planet really discovered, then, was the seventh one, now known as Uranus, and the discovery created great excitement, and brought high honours to the astronomer concerned. It was found accidentally by the elder Herschel on March 13, 1781, while "sweeping" the heavens for interesting objects with a seven-inch reflector of his own construction. Those who have looked through a telescope will know that a star appears simply as a point of light, while the planets, being relatively close to us, all show an appreciable disk. Herschel recognized it at once by its disk as something different from a star, but, never dreaming of a new planet, supposed it to be a peculiar kind of comet. It was nearly a year later before calculations showed it to be a planet beyond the orbit of Saturn. It was found, on reckoning backward, that the planet had been many times observed as a star, and had barely missed discovery on several previous occasions. In fact twelve observations made by one astronomer proved exceedingly valuable in fixing its position at earlier epochs.

After the planet was discovered it was soon found impossible to reconcile these old observations with any orbit that would fit the observations made in the early part of the nineteenth century. Moreover, it began almost immediately to deviate from the orbit computed from the new observations and it was felt that some unknown influence was pulling it out of the path theory called for it to follow.

Mathematical astronomers working upon these residuals between its observed and computed positions felt that there must be some disturbing body pulling it out of its natural path, and were able to state the exact position in the heavens in which the disturbing body might be located at that time.

These laborious computations were carried out by Leverrier in France, and Adams in England, quite unknown to each other, with remarkable agreement in their results. As a result the planet was quickly found near the predicted position. This discovery of Neptune is rightly regarded as a great achievement of mathematical science, wherein small departures from the theoretical orbit are

made the clue for revealing the unknown disturber of the system.

The periods at present assigned to Uranus and Neptune are 84 and 165 years respectively. The possibility of the existence of planets farther out than Neptune has long been realized, although their great distances would mean that they would be extremely faint and inconspicuous. The discovery of the new planet, yet unnamed, has been along similar lines to the mathematical analysis which yielded Neptune.

The perturbations which such an unknown planet would have would be greatest for the outermost one, Neptune, but as this one has been under observation only about half its period, the next best one for examination is Uranus. When the perturbations of Neptune were allowed for, the observed positions of Uranus almost, but not quite, agreed with the theoretical positions at the different epochs. There still remained, however, residuals of a second order of magnitude which were felt to be real. Among others, Gaillot and Lowell have subjected these residuals to a rigorous mathematical treatment, hoping thereby to prove the existence of such a trans-Neptunian planet, and to reveal its position.

The story of Lowell's life is very interesting. Graduating from Harvard in 1876 after a brilliant university course in which he specialized in mathematics, he entered mercantile life in Boston and soon amassed a fortune. All the time in business, though, he was interested in astronomy and having made his fortune, he decided while still in the prime of life to spend his wealth and the remaining years in astronomical research which had so appealed to him. The result was the establishment of the splendid Lowell observatory at Flagstaff, Arizona, an institution which I believe by his will is endowed permanently.

While Lowell's chief interest centered on the planet Mars, he found time to bring his fine mathematical training to bear on the problem of a planet beyond Neptune. In an exhaustive memoir published in 1915, he concluded that the admission of an outside perturbing body would reduce the residuals in the computed orbit of Uranus by 95 per cent. The mass he determined for it was 6.7 times that of the earth, or slightly less than half that of Uranus.

The only fly in the ointment was that there were two possible solutions for the planet's position, one giving it in the diametrically opposite part of the sky to the other. Apart from the question of position the elements agreed perfectly. It was accordingly necessary to examine two regions of the sky for an object between the 12th and 13th magnitude with no appreciable disk.

Visual observations clearly would not be of much value in spotting the object, as it would in appearance be almost like a star. It would be necessary to detect a change of position in the object that would conform to its orbital motion about the sun. That could most easily be accomplished by the comparison of photographs of the suspected regions made at short intervals of time apart. The earlier research work was laborious, due to inefficient instrumental equipment for this type of work, but early last year a specially designed photographic telescope was secured. The comparison of photographs of the suspected region made with this new equipment early in this year showed a peculiar object. The photographs from night to night indicated that its motion relative to the stars was of the right order to assume that it was the planet Lowell had so firmly believed in.

In connection with its discovery, first credit should be given to Lowell and similar investigators for backing their faith with mathematical investigations that forced conviction as to the presence of such a disturbing body. Interest attaches to the case also of the young student, Tombaugh by name, who, using the blink-microscope, had the observational skill to detect the object in the comparison of the photographs. Press despatches indicate that it was the value of some work performed with a reflecting telescope of his own construction that won the young student a place on the staff of the observatory. He, too, should have a share in the credit for the achievement.

The planet is one whose presence is revealed only by photographs, save in the case of the largest telescopes. It would need to be 10,000 times as bright as it is to be visible to the unaided eye, hence it will not thrill the ordinary person like Jupiter or Saturn.

While many observatories have photographed the planet since its discovery was announced, it is highly desirable that its exact

position on different dates in the past be obtained. To that end it is likely that a search will be made of the great collection of photographs at the Harvard College Observatory. These cover the past 40 to 50 years, and should yield invaluable information of its orbital path during recent decades.

XXXI.—THE PACIFIC SCIENCE CONGRESS

(May 9, 1930)

While the subject announced may not seem to have much connection with astronomy, the subject these radio talks usually deal with, yet there is some connection, in that for the first time astronomical research is given a place upon the program of this Congress I am about to describe. The fifth of these Scientific Congresses of the peoples on the Pacific is to be held in Canada in the Spring of 1932 and I thought a summary of the origin and work of the Congress might be of some interest to people residing in Victoria and the mainland. The sessions will open in Victoria, and conclude in Vancouver, and many representative scientists from countries all around the Pacific will be our guests on that occasion.

The idea of these Congresses really originated in the casual exchange of views relative to problems of exploration by men of the various countries bordering on the Pacific or having interests therein. Formal organization was first mooted at the Australian meeting of the British Association for the Advancement of Science in 1914 but due to stress of war the question was shelved until 1918 at the semicentennial anniversary of the University of California. At the conclusion of those anniversary meetings the representatives of many of the Pacific countries met and informally decided that a Conference of interested scientists in Japan, China, Australia, New Zealand, the islands of the Pacific as well as the United States and Canada should be held at an early date in the future. Such a Conference it was felt would facilitate the study and might evolve a solution of some of the pressing scientific problems of the Pacific.

An organization known as the Pan-Pacific Union, in Hawaii, existing for the purpose of promoting good fellowship among peoples of the Pacific, secured a grant from the Hawaiian Govern-

ment and called the first conference in Honolulu in August, 1920. This was known as the first Pan-Pacific Scientific Congress. Later the term Pan was dropped. The purpose as stated in the circular calling the Congress was to outline the scientific problems of the Pacific and to suggest methods for their solution; to make a critical inventory of existing knowledge and to devise plans for future studies. Some of the divisions of science touched upon were, (1) Anthropology, dealing with the migrations, dispersals and the characteristics of each race. (2) Marine biology, dealing with the fish resources of the Pacific, and the necessity for their conservation. (3) Geography, stressing the need for further deep sea soundings, continued magnetic surveys, and more co-operation in the securing of Meteorological data. These are only a few of many phases of scientific research discussed. About 120 delegates attended and, apart from the benefit of the scientific discussions, much good feeling was created in the various outings arranged.

The second Congress went by invitation to Australia in the autumn of 1923, opening in Melbourne, and closing in Sydney on September 3rd after sessions lasting 12 days. A sum of $30,000 had been appropriated by the Commonwealth Government towards the expenses of the delegates, some of the more prominent of whom received assistance in the matter of their ocean fares. Between 80 and 90 overseas delegates were in attendance, there being three from Canada.

The hospitality of the Australians was highly praised and not only in Government quarters was this true, but the various organizations and societies as well as individuals vied with each other in providing suitable excursions and entertainment for their guests. Everyone, from the highest to the lowest, seemed to know that there was an important gathering of scientists in their midst, to whom it was desirable to show all possible attention. The reason for all such solicitude was not a greater appreciation of science on the part of Australians than is manifested by people of other countries, but rather that they recognized the unique opportunity of cultivating international goodwill. The Australians took the Congress seriously, though, for they hoped to obtain through it help in solving some of their problems. Australia seems to be a land of pests;

we have all heard of the rabbit pest, but it is a minor one compared to the prickly pear pest, the blow fly, the tick pest and various plant pests that affect wheat, sugar cane and bananas. In man's conquest of the tropics no problem is more important than the control of these pests, and it is a matter for sincere congratulation that members of Congress were in some matters able to offer advice which has been of great economical benefit to Australia.

One criticism made of the Australian gathering was that it stressed applied science to the total exclusion of pure science. It should always be kept in mind that the more difficult and pressing any problem is in applied science, the more necessary it is to study that problem broadly and deeply as a problem of pure science.

The third Congress was held in Japan in 1926, and although that country was just recovering from the terrible earthquake of 1923, nothing was left undone by the Imperial Government of the Island Empire that would make for the success of the meeting or the comfort and pleasure of the 200 overseas delegates. A definite organization had now been drawn up in which two distinct objects were sought. (1) To promote co-operation in the study of scientific problems affecting Pacific countries, and (2) to foster bonds of peace between these peoples.

Many resolutions of a far-reaching nature were passed. It was urged that there be a greater exchange of research workers as well as teachers and professors, so as to develop a wider viewpoint and to become acquainted with the methods of other workers. Over 400 papers were presented in the various divisions, and it is significant that English was made the official language of this and future Congresses.

The fourth Congress was held last year in Java, 165 overseas delegates attending. Papers related largely to problems in agriculture, for in the Dutch East Indies agriculture is the leading source of the livelihood of the people. The papers were not, as a rule, presented to the sections, but an outstanding authority summarized the main points of many papers relating to the same subject. The information in all the physical and biological sciences, as well as in agriculture, was brought up to date, and 28 resolutions of a general nature were passed.

The fifth Congress comes to Canada in 1932, and the National Research Council have had the matter in hand and have secured Chairmen of the various divisions of the biological and physical sciences upon which papers and discussion are to be invited. The fifteen sections are the following:— Agriculture, Anthropology, Botany, Animal Diseases, Entomology, Fisheries, Forestry, Zoology, Astronomy, Geodesy and Geography, Biology and Oceanography, Meteorology and Terrestrial Magnetism, Radio, Seismology and Volcanology. The Chairmen, with members of their Committee, subsequently chosen, are to arrange for papers upon their own particular section. In addition, joint meetings are to be arranged, four of which will comprise the whole personnel of the Congress and will deal with the general theme of science as related to the four basic industries of this province,—mining, forestry, agriculture and fishing.

These matters were arranged at a meeting of the Executive Committee of Congress with Chairmen of the various sections, which meeting was held April 16th and 17th in Vancouver. Other general arrangements were made, the full details of which will be sent out from headquarters about the 2nd of May. While the meetings, which will open in Victoria on May 22nd two years hence, and close in Vancouver June 10th, are far in the distance, it is not too early to bring to the attention of our people the great opportunity which will be ours two years hence of entertaining several hundred representative men of science from the various countries bordering on the Pacific Ocean.

XXXII.—VENUS, THE EVENING STAR

(June 13, 1930)

For the next couple of months Venus will continue to be the so-called evening star, setting from one to two hours after the sun. It will gradually increase in brightness to the middle of October, although its more southerly position in the western skies at that time is unfavourable for observers in the northern hemisphere.

While I have permitted the designation of evening star to be used in reference to Venus, it must be understood that it is used

only in the popular sense of the expression. Venus is not a star at all; the stars are a million or more times as large as Venus and are self-luminous, whereas Venus and the other planets shine merely by reflected sunlight. But in the popular minds the terms evening star or morning star are understood to refer to the brightest heavenly body seen in the western or eastern skies and no harm will be done if we keep clear the distinction between a planet like Venus and a star.

In Roman and Latin mythology, Venus was the goddess representing beauty and growth in nature, especially in gardens, where the Roman practical sense would naturally see these. This Latin deity was within historical times entirely absorbed by the Greek Aphrodite, the goddess of love and beauty. Among the Geeks this planet symbolizing the goddess had two names, Phosphorus as a morning star and Hesperus as an evening star.

For several weeks at maximum brightness Venus is so brilliant that it can be seen by the naked eye in the daytime; occasionally it is bright enough to catch the eye at once, but usually it is seen by daylight only when one knows precisely where to look for it. It is never seen around midnight for the simple reason that as it moves about the sun in an orbit within our own it never gets a sufficient angular distance from the sun to be seen at midnight.

Venus goes around the sun in 225 days at a mean distance of 67 million miles while we are distant 93 million miles. These figures, you understand, are approximate only. The planet's diameter is about 7,700 miles while the earth's is 7,920 miles. Its mass is about 4/5 that of the earth as it is slightly less dense as well as being smaller. Nevertheless, it is much like the earth, so much so, that among the main planets it is often spoken of as the twin sister of the earth.

As it receives all its light from the sun its brightness will depend, for one thing, upon the portion of the illuminated hemisphere which is turned towards us at any time. In this regard it is exactly similar to the moon for at half-moon phase we see exactly one-half of the illuminated surface while at the full moon the whole of the illuminated disk faces us. And just as the moon shows these so-called phases, so does Venus. Its brightness depends, however, not only upon the phase but also upon its distance from us. You

can readily understand the situation if you picture two runners running on circular tracks, one within the other, the radius of one track being 67 and of the other 93. If they start off together on the same side of the centre they are only a distance of 93−67 or 26 units apart, whilst when the inner one (Venus) with its more speedy revolution pulls away from the outer one (earth) and gets on the opposite side of the sun they are then distant 93+67 or 160 units of distance. The latter distance being about six times the former, we readily understand how much less luminous it becomes on that score. Taking the two things into consideration it is found that about 36 days before and after its nearest approach to us it shows its maximum brightness. This year maximum brightness occurs October 18th, but as it is then pretty far south it is not so well placed for northern observers who will see it better during the summer months.

Apart from the phases, which cannot in general be detected by the naked eye but which are interesting when viewed through a telescope, the planet is not a particularly striking object for observation. The surface appears as if completely covered with clouds, presenting a sameness out of which only at rare moments of good seeing emerge some ill-defined markings. From these surface markings it was at first supposed that a period of rotation of about 24 hours had been established. Later this rotation period was discredited, as was also the idea that its period of rotation and revolution are alike, namely, 225 days. While we are much in the dark as yet as to its true value, certain considerations of another character indicate that the period is likely of the order of a month.

The evidence that Venus has an atmosphere is conclusive. Near the crescent phase, when it is almost in line with the sun on the near side, the horns of the crescent extend considerably beyond the diameter, showing that more than half of the surface must be illuminated by the sun or visible to us. As the planet comes almost in line with the sun the cusps actually run together, forming a complete ring around the disk, which phenomenon has actually been seen on several occasions. It is due to the diffuse reflection of light by the planet's atmosphere, like that which causes our twilight.

The atmosphere can thus be calculated to be at least 4,000 feet above the visible surface. While this is much less extensive and

less dense than the earth's, being comparable perhaps to that of the earth above the high clouds, yet if the visible surface is a cloud layer there may be any amount of an atmosphere below it. We have not as yet been able to penetrate beneath the visible surface but specially sensitized plates may yet make the region accessible. These have already demonstrated the fact that the diameter in ultra-violet light is two per cent. greater than in infra-red.

If the outer atmosphere contained oxygen or water vapour in any quantity such could be detected by characteristic lines in the analyzed light. There seems to be but little evidence of these elements, so necessary to the existence of life, and it is concluded that the amount of oxygen in the atmosphere above the visible surface is less than 1/1000 of that in the earth's atmosphere while water vapour seems also negligible in quantity.

However, the whole question seems to rest upon the nature of the visible surface. If this is a solid bank of clouds then there may be much more atmosphere underneath the clouds with accompanying oceans and other bodies of water on the actual surface. In that case conditions would favour life as existing upon the earth, but much more research is necessary before anything more than guesses can be made.

In any case the planet is an interesting object this summer for those with small telescopes.

A GREAT HOBBY*

By A. W. Megget

The dawn of science began when our ancestors discovered there were certain fixed laws in Astronomy, and the discovery of these laws laid the foundation of modern progress, mathematics, spherical trigonometry. The laws of motion are the very foundation of modern mechanics.

Astronomy provides man with an idea of his proper place in the great universe around us.

"The savage who sees the earth and sky meet at a distance of only a few miles, imagines his inverted bowl of sky covers the universe and that fortunately he is situated in the centre of it, but if he climbs to a high mountain and finds the land stretching out on every side he has to readjust his opinion of the size of the world."

The scientist climbing the heights of knowledge finds that he must continually re-adjust his opinion of the size of the universe to accord with his changing point of view. The last decade has seen a wonderful advance in astronomy, and stars seen by the naked eye constitute less than one millionth part of those visible in our large telescopes. A telescope such as the 100-in. reflector at Mount Wilson, California, brings to our view thousands of island universes which a few years ago were thought to be gaseous nebulae, but are now found to be crowded with millions of stars. The largest of these is the well-known Andromeda Nebula, and we are told that the same laws which govern our own particular universe hold good throughout all of them. To-day we stand in silent awe at the great truths astronomy teaches us, and the unity which permeates all creation.

It has been said that if the skies were always cloudy and mankind had never seen the stars, we should be thrown back to the knowledge of the middle ages, and civilization with its wonderful

* A paper read before the Winnipeg Centre of the Royal Astronomical Society of Canada at its opening meeting, October 23, 1929.

inventions would be unknown. Astronomers gaze on events which happened in some cases millions of years ago, so long does even the swift messenger, light, take to span the awful abyss which separates us from many of the stars.

Astronomy is the first, the most ancient and most beautiful of sciences. Through it we can become acquainted with the universe around us and learn something of where we are in space and what we are. Without the astronomical discoveries of the last 400 years we should still believe that this earth we live on was the sole reason for all that exists. Through astronomy we get a glimpse of the marvels of Creation. The sun upon whose life-giving rays life itself depends, is a star, and the earth is one of the eight planets which revolve round it at different speeds and distances in accordance with the universal law of gravity. The earth revolves round the sun at a distance of 93,000,000 miles with a speed of 66,000 miles per hour; it rolls through space without any support, an exact balance of the attraction of the sun and its own impulse keeps it in place.

To the naked eye on a clear night there are about 2,000 stars visible in each hemisphere, but a telescope shows us millions, and we know that all these are of much the same constitution as our own sun, in fact the stars are all suns, compared with many of which our sun is a dwarf. And can it be that all this universe around is devoid of life except for a second rate planet (Jupiter is 1,300 times the size of the earth) revolving around a very second rate sun?

These myriads of stars are placed in the Heavens for some purpose and it is one of the fascinating phases of astronomy to imagine that many of the stars we gaze on may have their own families of planets which may be the homes of human beings, perhaps not as we know them; but there may be other forms of life.

Practical Value of Astronomy

Through it man first acquired the habit of observation. When men found there were certain fixed laws, the discovery of these laws laid the foundation for modern progress.

Christopher Columbus' reason for thinking he could reach the East Indies by sailing west was based on astronomy: he saw that the sun, moon and stars rose in the east, travelled across the sky and set in the west, and concluded that the earth must be round, and therefore could be sailed round. Relying on this information he dared the perils of unknown seas and discovered America.

Arctic explorers depend largely on astronomy for accurately determining their position—navigation depends on astronomy.

Without the help of astronomy we should never know the correct time. No clock has ever been made that can keep perfect time. Astronomical time is given out by many observatories all over the world and taken from the stars, which are nature's clocks, and perfect time keepers.

Surveyors mapping out a country depend on astronomical data for their calculations. Useful elements such as helium gas were discovered through the means of that marvellous astronomical instrument, the spectroscope, which has so advanced astronomical knowledge during the last 50 years.

I want to speak a few minutes on the pleasure anyone can derive from even a slight knowledge of astronomy. Everybody should have a hobby as a complete change from his, or her, everyday vocation, especially a business man, shut up in an office all day. What grander or more interesting hobby can anyone find than the study of the Heavens for "The Heavens declare the Glory of God". The marvels of astronomy transcend anything we know of in this world of ours.

Astronomy for an amateur is inexpensive. In fact, much pleasure can be derived from it without any scientific apparatus at all, just our two eyes and a little time spent in making a start and learning the position of a few prominent stars and constellations. Learn to know a few of them by name. You will soon get on friendly terms with the stars and welcome them as they appear in their seasons as old friends. Once you make a start, no persuasion will be needed to make you carry on. Astronomy is not a difficult study to pursue. Don't let the bugbear of mathematics deter you from making a start at this fascinating study. It can be studied and enjoyed by anyone without a knowledge of higher

mathematics. Garrett P. Serviss, who has written so many interesting books on the stars, says: "The idea that astronomy cannot be studied without a knowledge of higher mathematics has kept thousands from enjoying the delights of what is both the oldest and most wonderful of sciences."

Astronomy is Uplifting

Who has not been thrilled by the living words of some of our immortal poets, or carried away by the silvery tongue of some fine orator? Listen to these words written by the Greek philosopher Euripides, 400 years B.C.: "Happy is the man whose lot is to know the secrets of the Earth. He hastens not to work his fellows harm by unjust deeds. But with rapt admiration contemplates Immortal Nature's ageless harmony, and how, and when her order came to be. Such spirits have no place for thoughts of shame." Is any poem finer than the book of the skies written in letters of fire across the Heavens? I think that the surprise one gets when looking for the first time through a telescope at the torn and rugged scenery of our nearest neighbour, the moon, is greater and more lasting than any words penned, or uttered by the tongue of man.

Music is said to be the most divine of all our gifts. Who has not listened enthralled by some grand piece of music sung by a large choir or played by a symphony orchestra? Listen to the Hallelujah Chorus if you can, without feeling there is something beyond this mortal clay. A pupil of astronomy stands daily in the presence of the Infinite. Sir Oliver Lodge says: "The scientifically apprehended universe is a gorgeous palace, but it already shows signs of dissolving into an immaterial, an insubstantial pageant, and through the wrack the turrets of the City of God are beginning to appear."

An artist can paint a picture the memory of which we carry with us as long as memory lasts. I remember seeing a startling picture by Burne Jones, "The Sea shall give up its Dead". This picture hangs in the Tate Art Gallery in London. I shall never forget it. The same day I strolled through the British Museum and there through a glass case I saw the mummy of the great

Egyptian King Rameses—the Pharoah who held the Israelites in captivity, whose soldiers were swallowed up by the Red Sea. Where is now the pomp and glory of those ancient Egyptian days? Nothing left but this poor shrivelled mummy and the magnificent ruins of huge temples and tombs buried beneath the burning sands of Egypt. We read lately of archaeologists unearthing the ruins of what was once the rich and prosperous city of Ur in Chaldea—Abraham knew this city 5,000 years ago, but there it lies a heap of buried ruins to be unearthed and discovered again in this 20th century.

The life of this earth compared with the eternal stars is but a flash. A little over three centuries ago this earth was thought to have been in existence about 6,000 years, but modern astronomy tells us that we should have to multiply this by at least 500,000 to say THIS was the beginning of the earth and the age of the earth compared with the vast shoreless time and space which surrounds us is no more than a grain of sand on the shores of the Atlantic ocean.

The strange thing is that to-day we see the same stars and constellations shining down on us as shone on the Ancient Babylonians (to whom the sun, moon and stars were gods), the Chaldeans, Egyptians, Heroic Greece, and the mighty Roman Empire—the hand of time has wiped out these ancient peoples—but there overhead shine the same stars which silently witnessed them at the height of their glory. There is nothing which gives us such a realization of the depths of space as this thought, that though some of the stars we see are moving through space at a speed of over 200 miles per second, and have been doing so for 6,000 years, and the sun is also dragging us through space towards the star Vega at a speed of nearly 1,000,000 miles every 24 hours, yet with the naked eye we see the stars in the same position in the sky as they appeared to those ancient peoples.

It is said that the Chaldeans were more familiar with the stars and constellations than the modern business man in one of our large cities with the rush and hurry of business and the glare of the electric lights. Let me enumerate a few of the wonderful sights which can be seen by the possessor of a small telescope.

There are about 2,000 stars visible to the naked eye in each hemisphere—that is stars down to the 6th magnitude—a 6th magnitude star is 100 times less bright than one of the 1st magnitude. The bright stars Altair and Aldebaran are what are called standard 1st magnitude stars. Six stars of the Great Bear are second magnitude stars—a 4th magnitude stars is as bright as the star Megrez at the junction of the handle to the bowl of the dipper —and it is interesting to know that if our blazing sun was to be removed even only to the distance of the nearest star, Proxima Centauri, it would shine to our view as a star of the 4th magnitude like Megrez.

The moon, our nearest neighbour in space, 240,000 miles away, is the best object to begin your voyage through space. Its deep craters, lofty mountains, and terminator which marks the course of advanced daylight across its surface, now lighting up a mountain with its silvery light, now slowly creeping down the sides of a deep crater. Imagine what it must be like on the moon, no protecting air, and its day as long as 14 of ours, when the fierce rays of the sun must bring the moon's surface to boiling point—and then the long lunar nights equal to 14 of ours, when the surface of the moon must be plunged into a temperature which would make our north polar weather seem balmy in comparison. Then there are the wonderful sun spots which seem to have so much influence on our terrestrial weather. Some of these sun spots are many times larger than our earth.

Then we can often see the planet Mars, and wonder at its so-called canals. Are they the work of human beings? And there are the two tiny moons of Mars not visible except in the largest telescope. But what wonderful moons they are! Phobos, the inner moon, whirls round Mars in a little over 7 hours, and as the Martian day is about the same length as ours, Phobos crosses the Martian sky three times every day.

Then a small telescope will show us the great planet Jupiter, 1,300 times the size of this earth, with its wonderful equatorial cloud belts, and four of its large family of moons. We can view the wonderful rings of the planet Saturn, which are one of the wonders of astronomy. Then we can turn our glass on some of

the stars, and see them flashing like beautiful jewels of every colour. The blue of Vega, the golden colour of Arcturus, the orange colour of Aldebaran and Betelgeuse, the white diamonds of Spica and Rigel. Many fine star clusters are to be seen. The double cluster in Perseus, several in Sagittarius, Praesepe, the Manger in Cancer; the great globular cluster in Hercules needs a large telescope to show its thousands of stars.

Then we can see many binary stars of contrasting colours, such as Albireo in Cygnus, gold and blue, Castor, yellow and blue, Mizar, two white diamonds, and the multiple stars Gamma Andromedae and Epsilon Lyrae, the latter to the unaided eye is a single stars, but a telescope shows it to be a system of 4 stars. Some of the nebulae are visible in a small telescope. Orion is the finest sight with its so-called Trapezium of 4 different coloured jewels. Andromeda needs a large telescope. The Ring Nebula in Lyra can be seen and is so large that could we imagine the Solar System placed within this ring the planet Neptune 30,000,000,000 miles distant from the sun would revolve within the ring.

There is plenty for us to see, but how many people go through life and give no heed to the call of the stars, and what they are trying to tell us. Let anything unusual happen in the sky, and everybody is interested; an eclipse of the sun or one of those ghostly visitors of space, a comet; or a shower of shooting stars, or what we saw a few years ago, the planet Venus in broad daylight. Many of my listeners will remember the crowds of curious people gathered at every street corner, wondering what the strange sight meant.

There is little romance in our rushing present day life. As a rule everything is apt to be judged by its money value. A writer says: "It is nice to have plenty of money for what money can buy, but take care in your pursuit of money you do not miss something which money can not buy. There are hundreds of people in Winnipeg who can say as Carlyle said in his old age, "Oh, why did not someone teach me the constellations which we have always overhead, and make me at home in the starry heavens?"

This branch of the Royal Astronomical Society is a great help to anyone who wishes to enter into the fraternal company of star

gazers, and to realize something of the marvels of this great universe. We are supplied with a monthly magazine which is more than worth the membership fee of $2.00, and all members are given an opportunity of preparing something on matters astronomical, and of appearing before the Society and giving a talk or paper on some subject, the preparation of which I find is in itself a great help to the giver, and I hope, of some interest to the other members of the Society. We find the officers are always ready to give encouragement to the bashful or timid member, and to aid one another and encourage the pursuit of astronomical knowledge and to try to arouse general interest in this great hobby.

I have been a member of this Society for 8 years and can vouch for the kindly help and encouragement given, and recommend the study of the stars to everyone as THE GREAT HOBBY. My only regret is I did not have the opportunity of taking up this fascinating study in my younger days.

Deer Lodge,
Winnipeg, Man.

SEMI-REGULAR VARIABLES*

One of the most promising lines of attack upon the perplexing problems of the internal constitution of the stars, lies in the study of those which show variations in their luminosity, not eclipsing binaries (although they provide us with much invaluable information), but those stars whose intrinsic brightness is variable. A great deal of work has been done on the two great groups of variables, the Cepheids with periods of a few days, and the Mira variables with periods around two or three hundred days. Despite this, we are still without a really satisfactory theoretical explanation of the characteristic behaviour of these stars.

Now between the Cepheids and the Mira stars there is a gap where variables (we are still excluding the eclipsing type) are very scarce. These intermediate stars, of periods roughly between 40 and 100 days, are none the less interesting, and the astronomical world owes a debt to Gerasimovic for the extensive work he has recently published on them,† drawing attention to their importance and some of their more striking characteristics. Not only has he utilized all the photometric material available at Harvard (more than 20,000 magnitude estimates for 31 variables), making careful investigation into the light curves of a number of these stars, but he has also discussed fully the present position of our knowledge concerning this class of variable.

As is well known, the light curves of Mira stars do not in general show the great regularity found with most Cepheids. The stars intermediate between these two groups are still more erratic, however, to such an extent indeed as to justify the term "semi-regular variables". The "period" here is usually far from constant and, in fact, is in some cases difficult to define at all.

Some time ago a relation was put forward by Shapley which connects the periods and spectral types of variable stars. This relation is possibly only statistical in character (further research is needed on this point), but the great majority of variables —

*Seminar Talk No. 168.

†Harvard Circulars 321, 323, 333, 338, 340, 341, 342.

whether of the cluster, Cepheid, RV Tauri or Mira type—obey it. These stars, in which the nature of the variation is probably fundamentally the same, are said to form the *principal sequence* and Gerasimovic divides his intermediate stars into two groups: (1) those which belong to this "principal sequence", and (2) those which do not.

Group (1) is formed by the RV Tauri stars. These objects are of particularly great interest since not only do they stand intermediate between Cepheids and long period (Mira) variables but they also have important connections with both these other groups. Their characteristic properties, according to Gerasimovic are:—they vary continuously in brightness; the light minima are alternately shallow and deep; the difference in brightness between successive minima may interchange; the light curve varies in shape and may be anything from the β Lyrae to the δ Cephei form; maximum light is slightly variable and other irregularities may complicate the light variation considerably. There are only twelve of these stars known with certainty. Details concerning photometric work and radial velocity observation (Mt. Wilson, unpublished) are given. A pronounced likeness to the Cepheids is evident. This leads Gerasimovic to suggest that in RV Tauri stars we indeed have a normal Cepheid variation (period P) upon which are superposed various irregularities, the chief being a smaller oscillation of period. 2P.

It is natural to seek for a physical model which will show these properties. RV Tauri variation cannot well be explained by the pulsation theory advocated for Cepheids by Eddington and Shapley, since there the fundamental (P) wave must be the longest. Other more complicated models may be suggested but they offer mathematical or physical problems yet to be solved.

The remaining variables (group (2)), outside the "principal sequence", are also discussed in these papers, as far as present knowledge will permit. They are divided into three groups; periodic variables, those related to the μ Cephei stars, and cyclic variables. The first have a fairly well defined period with comparatively small erratic or systematic changes. In the second group we have variables of small range and period (*e.g.*, 90 days), with a slow

irregular oscillation superposed. The latter slow changes are similar to those shown by the α Cephei stars (*e.g.*, α Orionis, α Herculis). In the last group irregularities are more predominant, it is frequently difficult to define a period and often the most that can be said is that the star passes through certain states in a definite order. A complete series of such states is termed a cycle and there are "regularly cyclic" and "erratically cyclic" variables.

All this classification is, of course, tentative, since comparatively little work has been done on these stars, and as yet not many examples are known. Since in most cases the range of light variation is small, discovery is more difficult than with other classes of variables, but we may expect a greater number to be found in the future than has been done so far. Observational work on the known examples is urgently needed. Very little is known of the radial velocities. A little work has been done at Mt. Wilson, and observations on two stars, SV Ursae Majoris, and V Ursae Minoris, have been made recently at Victoria. Much more work, however, will probably be required before much light is thrown on the true nature of these objects.

Their irregularities and their comparative scarcity in the sky suggest that these stars are subject to a certain degree of dynamical instability. It is quite possible that they are in a brief transition phase between two relatively stable conditions. Their development and evolution are, therefore, of no little interest and importance.

R.O.R.

Dominion Astrophysical Observatory,
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EINSTEIN'S VIEWS ON SPACE*

Professor Einstein does not wish you to accept his remarks on credit, but wishes to explain in the clearest way possible what he considers to be the trend of modern physics. What he has to say is his purely subjective opinion and it is by no means generally recognized. He thinks that he can give you at least some outline of what his view is of the future of the subject, but he does not want his remarks to be regarded as assertions. He wants them to be regarded rather as humble expressions of his opinion.

He will now concentrate our attention on the fundamental conceptions which lay at the beginnings of the foundations of physics. Professor Einstein makes clear what the prescientific view was and explains that the primitive concept was that of a rigid body and that relationships in the positions of rigid bodies preceded all ideas of space; that space was not a primary conception and that it was only through dealing with the position and relationships of bodies that the idea of space later emerged.

These ideas of space were due, of course, to contact relationships between bodies, and it is interesting to know that the classical science of the Greeks did not operate with space but exclusively with bodies. A rigid body is at the bottom of all the conceptions of geometrical space in Euclid.

The idea of a space continuum entered into science only when analytical geometry was invented by Descartes. How did the idea of space originally arise? The Greeks approached position in geometry by considering the position of bodies with regard to each other. This, of course, suggests a body of reference. We are familiar with coordinate systems in geography in the way in which they were used, for instance, in maps of geography.

Space appears expressed in body-like form by means of these axes of reference. This is really the way in which space as such entered into geography in the first place, and there was no physical basis for it. Relative motion occurs only with reference to one or more bodies. The great change took place in that view when Newton propounded his mechanics.

*On June 7, Professor Einstein gave an address at the University of Nottingham. It was in German and was translated by H. L. Brose.

The fundamental idea of Newton's mechanics was the introduction of the idea of force—that is to say, acceleration. Acceleration can be imagined only in reference to a really rigid body. It is a wonderful tribute to Newton's genius that he could go so far as to give space a definite physical reality.

He included it among the other realities. This is an aspect of his theory which has not been understood or has been neglected or misunderstood by some of his followers. Professor Einstein is very anxious that this particular point be emphasized—that space entered as a definite physical reality. It was a point which was missed even by the philosopher Kant.

A remark should be added about the physical idea of space. There are two aspects. In one of them space is to be regarded as the quintessence of positional possibilities of bodies, and, secondly, as a definite dynamic system of reference.

Professor Einstein emphasizes that Newton's space is to be regarded as absolute in the sense that positional possibilities of rigid bodies are to be considered as quite independent of outside forces, although he does not take temperature into consideration. This space is independent of all physical causes and is something which is absolute in itself.

In Professor Einstein's opinion a definite change in the view of nature after the time of Newton occurred when the idea of the electro-magnetic field was introduced by Faraday and Maxwell. The only real things at that time were bodies, space and time. Those were constructive elements from the physical viewpoint of the times. There were no others.

Faraday introduced the idea of "a field", and his contemporaries were bound to that method of introducing the idea of a state owing to the manner of thought of their time.

They, therefore, introduced a new body called the ether—or at least a new idea which they called ether—to represent a physical state. The introduction of ether was necessary in order to allow electro-magnetic phenomena to occur in space. This view received considerable strengthening at the hands of a Dutchman named Lorentz, who showed that in the electro-magnetic theory of states all ponderable bodies were those of ether and not of material bodies themselves.

Looking back now we might ask why ether as such was intro-

duced. Why not have called it "state of ether or state of space"? The reason was they had not yet got to realize the connection or lack of connection between geometry and space, and so they felt constrained to add to space a variable brother, as it were, which could be a carrier for all electro-magnetic phenomena.

The next change in the idea of space was comparatively small. It was due to a special theory of relativity sometimes called the restricted theory of relativity. Classical physicists had two separate continua which were to be regarded as a performing stage for continua. Those were space and time. Altogether, they formed four dimensional continua, three being in space and one in time.

But it had to be subdivided into two blocks due to the fact that there were a before and an after to satisfy the requirements of simultaneity. It was found, however, that to satisfy the demands of the constancy of propagation of light the subdimensions of space and time could not in this way be preserved or carried out.

The space-time phenomenon of the special theory of relativity was something absolute in itself, inasmuch as it was independent of the particular state of motions considered in that theory.

A definite change in our ideas about the rôle and constitution of space was due to the enunciation of the general theory of relativity, for which the ground had been prepared by the special theory of relativity. The law of inertia—we called it Newton's first law of motion—has shown a gap in its logic because we were not able to tell when coordinate systems were in acceleration or in rotation. We had no definite means of establishing it.

This is what is known in the general theory of relativity as "the principle of equivalents." It implies that an accelerated, coordinate system can be regarded in a certain sense as equivalent to what was known as the "inertial system." Watches and measuring rods were not found to operate in the same way for accelerated systems as for coordinate systems of the special theory of relativity.

To preserve the theory of relativity for the accelerated motions as well as for the uniform regular motions of the special theory of relativity, Euclidian geometry, having been found to be too restrictive, had to be rejected and a new geometry of space found. In order to preserve position possibilities of space we were compelled to regard them as no longer independent of positions of other bodies.

In other words, the privileged position of geometry had to be

given up and the viewpoint of covariants, as it is known to mathematicians, has been gained. This means that for a description of physical phenomena we must regard all generalized coordinates as of equal validity.

What, as general theory, has relativity then actually achieved? Professor Einstein does not want to enter into the question of the three experimental tests, which have all conformed to his suspicions, but the main achievement of the general theory of relativity is that it has advanced a uniformity of view of the physical world structure. The metrics of space can be derived directly from the full equation and it reduces the number of hypotheses which were originally thought necessary to account for physical phenomena. It has built, so to speak, a bridge between geometry and physics.

The next question is—What are the weaknesses of the general theory of relativity? Taking as a basis the Rummbey-Riff structure of space, we find that geometry and gravitation were conpletely represented by this structure, but what was to be done with the electro-magnetic phenomena which play an exceedingly important part in the world of physics?

In order to introduce these phenomena and to take them up in the general scheme of relativity it was found necessary to add to or impose upon the metric structure or Rummbey-Riff structure further terms which could account for electro-magnetic phenomena. Logically this structure had nothing to do with that which had been deduced from the elementary law of propagation of light. This duality in the geometrical structure of space leaves us in a rather indistinct state.

Professor Einstein feels that it should be possible to get a further form of this metrical space which will at one stroke comprise all phenomena in one set of equations, so that we shall not have a double metric structure of geometry and gravitation, on the one hand, and electro-magnetics on the other.

We want a system of equations which will take in all physical phenomena. This would be an enormous gain in the picture of the uniformity of physical nature.

As to the way in which the problem may be solved Professor Einstein says that it is a very difficult question to answer, and it has not yet been finished. His colleagues regard his view as a particular craze and do not support it. Nevertheless, he has faith

in the path along which he is proceeding, and although the theory is not yet quite finished, he has evidence that so far as he can judge the end is very near.

He says that there is a metrical structure of space, but that a full-time structure has yet to be determined. Then he wishes to find what conditions have to be made in the older structure or what modification in electro-magnetic phenomena may be included. He emphasizes that he is in no way taking notice of the results of quantum calculation because he believes that by dealing with microscopic phenomena these will come out quite by themselves. Otherwise he would not support the theory.

Then he says that a new idea which has occurred to him and on which he has been working is that the two elements in space should also be compared with direction. So far we have compared them only as regards size. This idea may give a clue. It occurred to him suddenly during a severe illness two years ago that by introducing the idea of direction he would be able to get the additional terms that are required in regard to space to allow electro-magnetic phenomena to be included with those of gravitation and geometry.

Professor Einstein's object now is to get mathematical conditions which will satisfy all his expressions and will comprise electromagnetic equations as well. The problem is nearly solved, and to the first approximations he gets laws of gravitation and electromagnetics. He does not, however, regard this as sufficient, though those laws may come out. He still wants to have motions of ordinary particles come out quite naturally.

This does not finish the program by a long way. It has been solved for what he calls "quasi-statical motions", but he also wants to derive elements of matter (electrons and protons) out of the metric structure of space. No doubt much work will have to be done before this is achieved. Professor Einstein thinks, however, that the way in which he has sketched the evolution of physical ideas is the only possible one—at least to him.

The strange conclusion to which we have come is this—that now it appears that space will have to be regarded as a primary thing and that matter is derived from it, so to speak, as a secondary result. Space is now turning round and eating up matter. We have always regarded matter as a primary thing and space as a secondary result. Space is now having its revenge, so to speak, and is eating up matter. But that is still a pious wish.

NEWS AND COMMENTS

The following Canadians attended the meetings of the American Astronomical Society held at Chicago, September 3-5: Professor and Mrs. Chant, Toronto; Director and Mrs. R. Meldrum Stewart, and Mr. and Mrs. C. C. Smith, Ottawa; Professor Campbell, Edmonton; Mr. Harper, Victoria; and Professor Kingston, London. They report an excellent programme of papers, and an interesting session at the Adler Planetarium.

Miss Alice W. Turner, M.A., who was engaged in astronomical computation at the Dominion Observatory during the summer, resigned the end of August to proceed shortly after for England where she will continue her mathematical and astronomical studies.

While presiding at the Seismological Section of the International Geophysical Congress at Stockholm, Professor H. H. Turner became suddenly ill on August 16 and died on August 20, at the age of sixty-nine. He had been Savilian Professor of Astronomy at Oxford University, and Director of its Observatory, 1893-1930. Many honours had been conferred upon him,—honorary doctorates, Oxford, Leeds, Sydney, Wales, Strasbourg, Durham and California; F.R.S.; F.R.A.S.; Corresponding Member of the French Academy, etc. He was famed for his work in many departments of astronomy, and geophysics,—longitude, star positions, variable stars, Eclipse investigations, sunspot theories, and the harmonic analysis of related astronomical and geophysical phenomena. Astronomers the world over have enjoyed and appreciated his interesting, humorous, constructively critical and sympathetic items which appeared monthly in "From an Oxford Note-Book" in *The Observatory*. He will be greatly missed at many scientific and international meetings where he has always taken a prominent part.

Mr. E. A. Hodgson left the Dominion Obbservatory on September 6, and he will proceed in the near future to the University of St. Louis to carry on seismological studies and investigations during the next two years, when he will return to Ottawa.

REDeL.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Telescopes and Observatory Equipment

It is interesting to note the progress being made in the manufacture of astronomical instruments. In our last issue Mr. J. W. Fecker gave some illustrations of his work, demonstrating that he is a worthy successor to Brashear and McDowell. A long and well illustrated article by Chief Engineer Meyer, of the Zeiss works, in the *Zeitschrift für Instrumentenkunde* gives a sketch of the development of the astronomical instruments of that well-known firm. A few years ago new life was given the firm of Grubb when it was taken over by Sir Charles Parsons and transferred from near Dublin to Newcastle-on-Tyne.

Just recently we have received an extensive catalogue of astronomical instruments and observatory equipment issued by Cooke, Troughton and Simms—a combination of three famous names. Troughton began business in the latter part of the seventeenth century and some historical instruments bear his name. In 1826 the instrument business of William Simms was amalgamated with that of Troughton. Among other instruments this firm constructed the 36-inch theodolite used for the great Trigonometrical Survey of India and the transit circles at Greenwich and the Cape of Good Hope. Thomas Cooke began to manufacture refracting telescopes at York in 1836, and about 1870 he constructed the great Newall 25-inch refractor, still in regular use at the University of Cambridge. For years it was the largest refractor in the world. The Cooke lenses are also well known. The Cooke firm also made many domes, one of their most famous being that at Greenwich which comprises more than half a sphere. The catalogue is well illustrated and includes also various observatory accessories, such as chronographs, plate measuring machines, coelostats, etc. The head office and works are at York, England.

The Einstein Shift of Solar Lines

As is well known, Einstein stated that according to his theory the lines in the spectrum of the sun should show a shift towards the red as compared with their positions obtained in the laboratory. A very careful and extended research into the question has been made by St. John, at the Mount Wilson Observatory, and his conclusion is that there is a shift as predicted. This result has been generally accepted. The problem, however, is extremely complex, as there are displacements and alterations in the lines due to various causes, such as the Doppler, Zeeman and pressure effects, and it is very difficult to disentangle the Einstein effect from them.

Further evidence is desired, and it may be of interest to refer to a paper by Burns, of the Allegheny Observatory, in the *Journal of the Optical Society of America* for April, 1930. Indeed, the Allegheny Observatory seems to be somewhat of a fundamentalist stronghold against the inroads of the Einstein theory. Burns' recapitulation of his discussion is as follows:—

> There seem to be the following objections to accepting as proven the predicted red shift of twenty-one parts per ten million for all the solar lines.
>
> First: the sharpest lines show very small shifts, and the shifts of lines of all intensities are small in the region of the spectrum where, on the basis of probable error, the observations are the best.
>
> Secondly: the striking intensity equation appears to be due in part to instrumental error and to be tied up with this error in such a way that the elimination of the error would have the shifts smaller than at present supposed.
>
> Third: St. John's velocity explanation of the intensity equation appears to be untenable in the light of atomic theory. An alternative theory, assigning the intensity equation to line dissymmetry, supposes the normal position of the solar lines to be even nearer to the laboratory values than the weak lines are found to be. And it seems to the writer that any explanation of the cause of the phenomenon should place the normal position of the lines, not in the middle of the shift, but at one end of the intensity equation, probably at the end of least shift.
>
> While these are serious objections to accepting the Einstein prediction as verified, it is well to defer judgment until certain gaps in our knowledge of solar and laboratory wave lengths have been filled. If interest in the red shift will induce spectroscopists to study solar lines with the highest possible resolving power, to measure the weak lines shorter than 5800A and to observe the spectra of many more vacuum sources; then the results

of these investigations will undoubtedly justify the large amount of attention which has been directed towards the red shift. These are matters for the future. For the present, although several text books are teaching our beginners that the proof of the red shift rests on at least as firm a foundation as that of the law of gravity, the writer thinks that the scientific mind does not usually accept as clearly proven a thesis whose proof requires the sort of treatment of the observational data that is necessary to bring the red shift of all solar lines to exactly twenty-one parts in ten million.

C.A.C.

Notice to Members of the Victoria Centre, R.A.S.C., Concerning Occultations of Stars by the Moon:

Members of the Victoria Centre will have noticed the request of Prof. E. W. Brown for observations by amateurs of occultations of stars by the moon. It is hoped that members of this Centre, possessing the necessary equipment, may be able to undertake observations of this kind. Dr. J. A. Pearce of the Dominion Astrophysical Observatory, Victoria, B.C., is prepared to assist with predictions of occultations and with the reduction of observations. Observers who may be interested are asked to communicate with Dr. Pearce, who will provide them with a list of predicted occultations, as well as with advice concerning the equipment necessary, and the general procedure to be followed in this type of work.

C. S. BEALS,
President, Victoria Centre, R.A.S.C.

The Royal Astronomical Society of Canada

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